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**FEASIBLE OPTIONS TO REDUCE GREENHOUSE GASES EMISSION
FROM AGRICULTURE AND ITS EFFECT
TO MICROBIAL COMMUNITIES IN INDONESIA**

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Abstract

Agriculture sectors can affect the net emissions of the greenhouse gases methane (CH₄), nitrous oxide (N₂O), as well as carbon (C) sources and sinks. Applying nitrogen fertilizers such as urea to soils have greatly increased N₂O emission, meanwhile keeping water flooding in rice field lead the emit of CH₄. Several options were propose for mitigate the greenhouse gases from agriculture land that including water management and apply organic material in rice field, while in arable field usually corporate a nitrification inhibitor with nitrogen fertilizer to reduce the emission of CH₄ and N₂O, respectively. In this paper, several works have been done to find-out the effectiveness and feasibility of options to reduce greenhouses gases fluxes from agriculture land. The experiments were consisted field works by collecting greenhouse gases by closed-chamber technique. The changes of microbial community structure were observed both by most probable number and standard plate count. The results suggest that 1) There are a potential for reducing emissions of N₂O by applying nitrification inhibitor in arable land, while The CH₄ flux was reduced by controlled water level in rice field, 2) Types of nitrogen fertilizers influenced the N₂O productions but did not significantly alter the structure of microbial communities.

INTRODUCTION

Application of nitrogen (N) fertilizers increases the amount of available N in the soil and improves the productivity of agricultural crops. However, up to about 60% of N fertilizers can be lost as pollutants through leaching of mobile N compounds such as nitrate (NO₃⁻) and emission of nitrous oxide (N₂O) as one of potent greenhouse gas. Inhibition of this process will reduce rate of nitrogen lost in the soil. Therefore, one of the effective strategies for reducing N loses in soil would be inhibition of nitrification (IPCC, 2007).

The rates of processes to emit N₂O mostly depend on the amount of NH₄⁺ and NO₃⁻ in the soil as well as other factors including soil water content, organic matter availability, temperature and pH of soil. In nitrification, N₂O is produced as a by-product of NH₃ oxidation. In nitrifiers denitrification, N₂O is an intermediate of the reduction of NO₂⁻ to N₂. Denitrifiers produce N₂O as an intermediate and possible end product of the reduction of NO₃⁻ to N₂. Beside these main sources, other sources like chemodenitrification or heterotrophic nitrification contribute substantially under some conditions to the production of N₂O.

Changes in CH₄ and N₂O emissions can substantially alter the overall greenhouse gas balance of a system. Intermittent drainage or late flooding of rice paddies can greatly diminish the seasonal emission of CH₄ compared with continuous flooding (Yagi et al. 1997). Changes in N₂O emissions following land use change from forest or grassland to agriculture vary between climatic zones, and the net impact varies with time. Applying nitrogen fertilizers to forests could increase the forest carbon sink, but may be accompanied by a net increase in N₂O; conversely, adding lime to acid forest soils can decrease the N₂O emission. Nitrification can have important effects on retention of nitrogen in the ecosystem such as loss of nitrogen in the form of nitrate via runoff and leaching to downstream ecosystems or through transfer of N₂O to the atmosphere.

Change in microbial population size is often observed after addition of organic or inorganic amendments (Sarniguet et al. 1992; Jumadi et al. 2008ac). Analysis of the spatial distribution of bacteria at microhabitat level showed that in soil subjected to different fertilization treatments show a shifted of bacteria population and more than 80% of the bacteria were located in micropores of stable soil micro-aggregates, which is a favorable condition for microbial growth with respect to water, substrate availability and gas diffusion.

A potentially effective strategy for N loss and reducing of N₂O emissions would be the inhibition of nitrification and denitrification. Nitrification inhibitors have been used in the field to improve the efficiency of fertilizers and to reduce both nitrate leaching and denitrification by maintaining the N in the soil as NH₄⁺ (Francis et al. 1995; Venterea and Rolston, 2000; Jumadi et al. 2008b). One of nitrification inhibitor is Dicyandiamide (DCD) acts by inhibiting the first stage of the nitrification process, the oxidation of NH₄⁺ to NO₂⁻, and by rendering bacterial enzymes ineffective (Di and Cameron, 2002). However, nitrification inhibitor can be hypothesized have a potential to inhibit the growth of bacteria due to the effect repress to enzymatic mechanism.

RESEARCH METHOD

Maize (*Zea mays* L.) seeds were sown in well drained fields of the State University of Makassar experimental farm in Makassar city, South Sulawesi province, Indonesia (5m asl., 05°11.221'S 119°25.750'E). The soil has loam-clay texture with soil types described as an alluvial. Three replicates of five treatments were laid out in a completely randomized design. The field has an area of around 48 m² (6 m wide x 8 m long) and each micro-plot measures 1.68 m² (1.2 m wide x 1.4 m long). The nitrogen (N) fertilizer types applied in the field were urea, urea coated neem (2.5%), urea coated neem (5%), urea coated DCD (5%).

The total rate of N applied in each treatment was 120 kg-N ha⁻¹. Plots without N application were also set up as a control. Soil samples were taken from triplicate plots at a depth of 0–10 cm and sieved through 2.00 mm mesh to analyze the NH₄⁺-N (ammonium) and NO₃⁻-N (nitrate) contents of the soil by calorimetrically. The percentage of N₂O-N lost per amount of N applied as fertilizer to the field (EF= emission factor) was calculated using the following equation $EF (\%) = (TF - TUF) / N \times 100$, where: TF = Cumulative N₂O flux emitted from the nitrogen-applied plot (kg N₂O-N ha⁻¹ season-1), TUF = Cumulative N₂O flux emitted from the non-nitrogen applied plot (control) (kg N₂O-N ha⁻¹ season-1) and N = Total nitrogen applied in the field (kg N ha⁻¹ season-1).

The percentage reduction of N₂O emitted from the fields with nitrification inhibitors was calculated using the following equation. $N_2O \text{ reduction } (\%) = (A - C) / (A - B) \times 100$, where A is the cumulative N₂O emission in the urea plot, B is the cumulative N₂O emission in the control plot, and C is the cumulative N₂O emission with a nitrification inhibitors plots. While, The rice field experiment site was located in the Maros district, South Sulawesi province as described by Jumadi et al (2012). The viable populations of ammonium oxidizers (AOB) and

soil fungi were estimated by most probable number (MPN) and standard plate methods, respectively.

RESULT AND DISCUSSION

Patterns of N₂O emissions were affected by fertilizer with different nitrification inhibitor (Fig.1). The urea+neem 2.5% plots started to release considerable amounts of N₂O at 10 DAS (days after sowing) or it was about 11 days after fertilizers were applied, and continue emitted N₂O until 25 DAS then declined thereafter. The urea and urea+neem 5% plot produced amount of N₂O at 25 DAS. In contrast, N₂O emission from the urea+DCD and control plots remained low during the crop season. Total N₂O emission during the cultivation period was highest from the urea plot, followed by the urea+neem 5% plot. An emission from the urea+DCD plots was higher comparing to control plot (Tab. 1).

The reduction of N₂O emissions by DCD counted 68%, more effective compare to neem amended (Tab.1). However, neem amended retained more NH₄⁺ in soil (Fig.1). The nitrification inhibitor is effective only in aerobic conditions, partly due to the greater contribution of denitrification to N₂O production under wet conditions, therefore we speculated that soil in the field was aerated enough to nitrification condition.

The emission factors (EF) range 0.4% to 1.2% (Tab.1). These EFs were not different with our previous studies in same field which were 0.71% to 1.6% (Jumadi et al, 2008). However, those EF values were higher compare with Andisol (a typical Japanese soil) amended with chemical fertilizer in a temperate region which were 0.05% to 0.35%.

Table 1. Total N₂O emitted from the field during cultivation, emission factor (EF), percentage of N₂O emission reduction by addition nitrification inhibitors and number of soil microbial properties (CFU, cell/gram dry soil) counted at 40 days after sowing.

Treatments	N ₂ O-N kg ha ⁻¹ season ⁻¹	EF (%)	Reduction(%)	AOB (10 ⁴)	Fungi (10 ³)
Control	0.33	-	-	94	12c
Urea	1.81	1.2	-	103	19c
Urea+Neem 2.5%	1.47	1.0	23	114	16c
Urea+Neem 5%	1.60	1.1	14	193	18c
Urea+DCD 5%	0.81	0.4	68	143	10c

In contrast, in acid oxisol in Puerto Rico, where a chemical fertilizer was also applied, emission factors ranged from 0.5% to 5% (Mosier et al. 1998). Hence, these emission factor values are possible mostly dependent on fertilizer types, and climatic and soil conditions.

Application of N fertilizers increased the concentrations of NH₄⁺ and NO₃⁻ in the soil (Fig. 1 and 2). The level of NH₄⁺ started at 2 until 25 days after sowing and significantly higher in the treated plot than control plots, but no differences in NO₃⁻ content were found at 10 and 25 DAS. At 40 DAS NH₄⁺ was monitored higher in urea plot due to urea was applied in this plot two days before soil sampling. The decrease in the NH₄⁺ content of the soil was accompanied by an increased in NO₃⁻ content, but found lower at 40 DAS which might be dense intensity of precipitation during days sampling lead NO₃⁻ were leached.

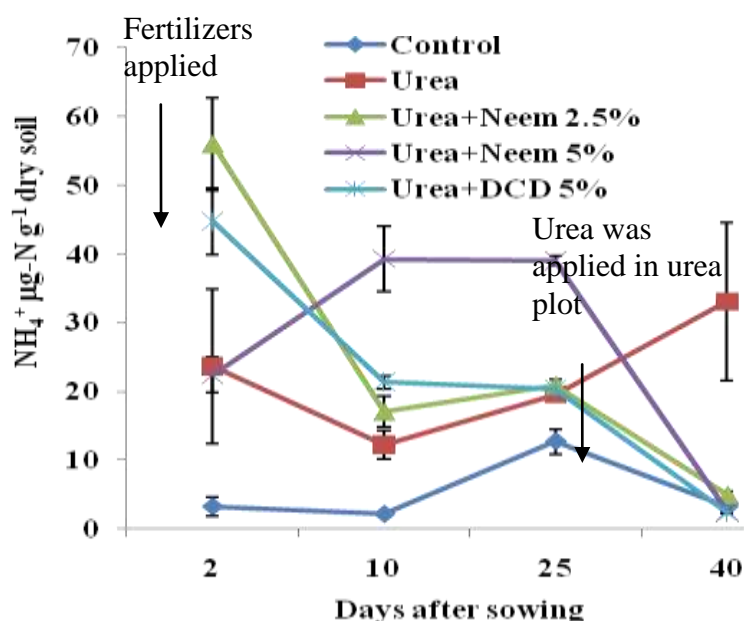


Figure 1. Change of NH_4^+ during cultivation. Vertical bar \pm indicated standard deviation

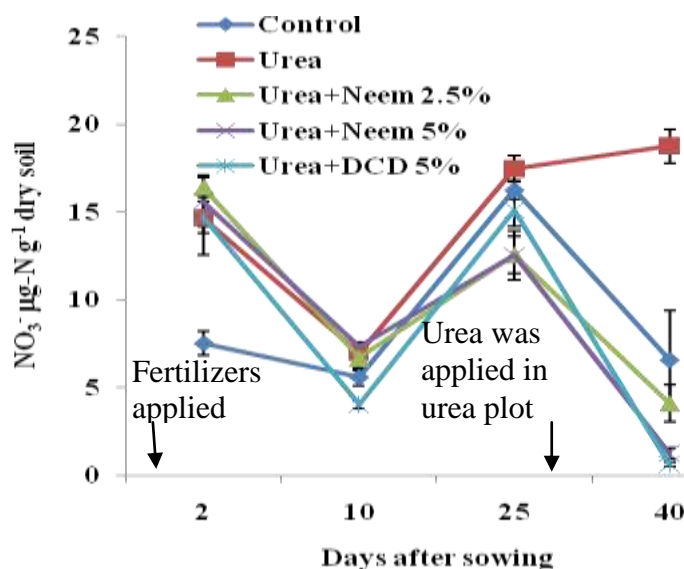


Figure 2. Change of NO_3^- during cultivation. Vertical bar \pm indicated standard deviation

The seasonal variations of CH_4 production from the rice field during the two cultivation periods are shown in Fig. 3. The rice field acted as a source of CH_4 during the observation periods. However, the controlled water levels (CWL) of the rice field exerted a significant effect on the reduction of CH_4 production, compared to the water level in the farmer practice.

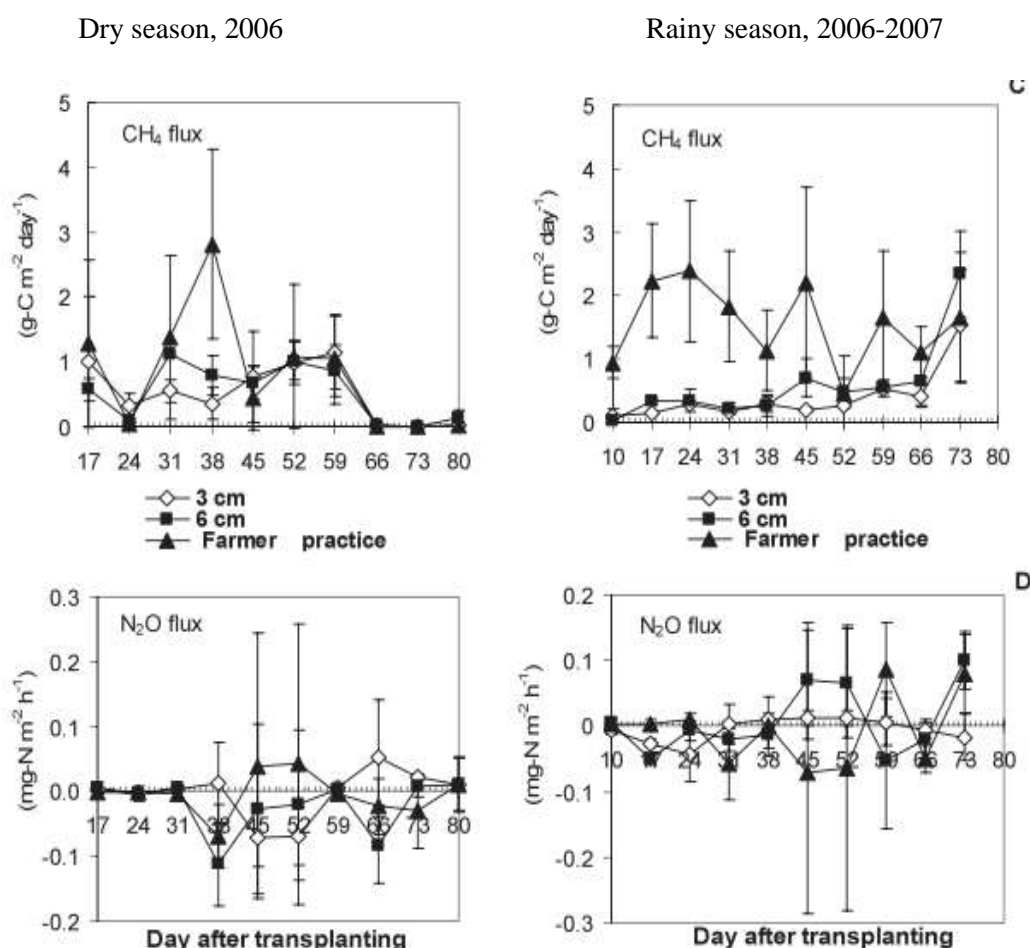


Figure. 3 Measurements of CH₄ and N₂O during a one-year period and effect of controlled water level

CH₄ flux was higher when the level of water increased in the rice field experiment in both cultivations. In the 1st cultivation (May 14, 2006 or 17 DAT), CH₄ fluxes monitored were 1.0, 0.6 and 1.3 g-C m⁻² day⁻¹ in the 3 cm, 6 cm and farmer practice plots, respectively, and then they decreased at 24 DAT when the water level in the field decreased due to the field drainage before the 2nd fertilizer application. In the farmer practice plot, the CH₄ flux peaked with a value of 2.8 g-C m⁻² day⁻¹ on June 4, 2006 or at 38 DAT, and then decreased to the values as recorded in the other plots at 45 DAT. In the 2nd cultivation, the CH₄ flux production was larger in the farmer practice plot than in the other plots until harvested. The CH₄ flux from the FP plot was consistently higher than that of other plots, except of the end of measurements at 73 DAT. The CH₄ flux in the FP plot rose sharply from 10 DAT and reached the highest recorded seasonal value of 24 DAT, and then fluctuated toward the end of cultivation. Meanwhile, CH₄ flux productions in the other plots were lower compared to those in the FP plot.

CWL below 6 cm in this area of rice cultivation is a promising option to mitigate the CH₄ production without hampering the rice yield as well as to save water. However, these practices cannot be easily adopted by the local farmers because they must determine whether the water level is above or below 6 cm and pump out water when the water level exceeds 6

cm, once a week. Therefore, convenient method to monitor the water level by the farmers should be developed along with some incentives to the local government to save water in order to reduce the CH₄ flux. The CH₄ flux in rice fields can be readily predicted by using soil redox potential indices (Yagi et al., 1997; Lumbanraja et al., 1998).

Water management by intermittent drainage or midseason drainage is one option to reduce the CH₄ flux from paddy field. However, this practice also enhances the rate of N₂O flux from the field during the drainage period (Cai et al., 1997). N₂O is produced in flooded paddy soils via nitrification of ammonium to nitrate and denitrification, and nitrate tends to accumulate in soils with an aerobic surface layer and under anaerobic condition, respectively (Arth et al., 1998; Suratno et al., 1998; Akiyama et al., 2005).

CONCLUSION AND SUGGESTION

There were substantial capacities of neem (*Azadirachta indica*) as nitrification inhibitors with repressions of N₂O emission and retained nitrogen in corn field. The use of urea+nitrification inhibitors can minimize nitrification rate and seems increased soil microbial population. The study also suggests that the addition of neem with urea is recommended as nitrification inhibitor. While, maintaining flood water levels up to 3 cm and 6 cm the N₂O emission was not stimulated, however, CH₄ emission were reduced.

REFERENCES

- Akiyama, H., K. Yagi and X. Yan 2005. Direct N₂O emissions from rice paddy fields: Summary of available data. *Global Biogeochem. Cyc.* 19, GB1005, doi: 10.1029/2004GB002378.
- Arth, I., P. Frenzel and R. Conrad 1998. Denitrification coupled to nitrification in the rhizosphere of rice. *Soil Biol. Biochem.* 30:509-515.
- Cai, Z., G. Xing, X. Yan, H. Xu, H. Tsuruta, K. Yagi and K. Minami 1997. Methane and nitrous oxide emissions from rice paddy fields as affected by nitrogen fertilizers and water management. *Plant Soil* 196:7-14.
- Di HJ and Cameron KC 2006: Nitrous oxide emissions from two dairy pasture soils as affected by different rates of a fine particle suspension nitrification inhibitor, dicyandiamide. *Biol. Fertil. Soils*, 42, 472–480.
- IPCC. 2007. Summary for policymakers. In: *Climate Change 2007: The physical Science Basis. Contribution of working group I to fourth assessment report of IPCC*. Cambridge University Press, Cambridge, UK and New York, USA.
- Francis GS, Haynes. RJ, Speir TW, Williams PH. 1995. The effect of a nitrification inhibitor on leaching losses and recovery on mineralized nitrogen by a wheat crop after ploughing-in temporary leguminous pasture. *Fert. Res.* 41:33-39.
- Jumadi O, Hala Y, Inubushi K. 2005. Production and emission of nitrous oxide and responsible microorganisms in upland acid soil in Indonesia. *Soil Science and Plant Nutrient*. 51 (5): 693-696.
- Jumadi O, Hala Y, Muis A, Ali A, Palennari M, Yagi K, Inubushi K. 2008. Influences of chemical fertilizers and a nitrification inhibitor on greenhouse gas fluxes in a Corn (*Zea mays* L.) field in Indonesia. *Microbes Environ.* 23: 29-34.
- Jumadi O, Hala Y, Anas I, Ali A, Sakamoto K, Saigusa M, Yagi K and Inubushi K 2008. Community structure of ammonia oxidizing bacteria and their potential to produce nitrous oxide and carbon dioxide in acid tea soils. *Geomicrobiology Journal*. Vol. 25: p. 381-389.
- Lumbanraja, J., S.G. Nugroho, A. Niswati, W.S. Ardjasa, N. Subadiyasa, N. Arya, H. Haraguchi and M. Kimura 1998. Methane emission from Indonesian rice fields with special

- references to the effects of yearly and seasonal variations, rice variety, soil type and water management. *Hydrol.Proces* 12:2057-2072.
- Mosier AR and Delgado JA. (1998). Methane and nitrous oxide fluxes in grasslands in western Puerto Rico. *Chemosphere*. 35 (9): 2059-2082
- Sarniquet A, Lucas O, Lucas M. 1992. Relationships between take-all, soil conduciveness to the disease, population of fluorescent pseudomonas and nitrogen fertilizer. *Plant soil* 145: 17-27
- Suratno, W., D. Murdiyarso, F.G. Suratmo, I. Anas , M.S. Saeni and A. Rambe 1998. Nitrous oxide flux from irrigated rice field in West Java. *Environ.Pollut.* 102:159-166.
- Yagi, K., H. Tsuruta and K. Minami 1997. Possible option for mitigating methane emission from rice cultivation. *Nutr. Cyc. Agroecos.* 49:213-220.
- Wittebolle L, Vervaeren H, Verstraete W and Boon N. 2008. Quantifying Community Dynamics of Nitrifiers in Functionally Stable Reactors. *Appl Environ Microbiol.* 74: 286-293.
- Venterea RT, and Rolston DE. 2000. Mechanisms and kinetic of nitric and nitrous oxide production during nitrification in agricultural soil. *Global Change Biol.* 6: 303-316.

